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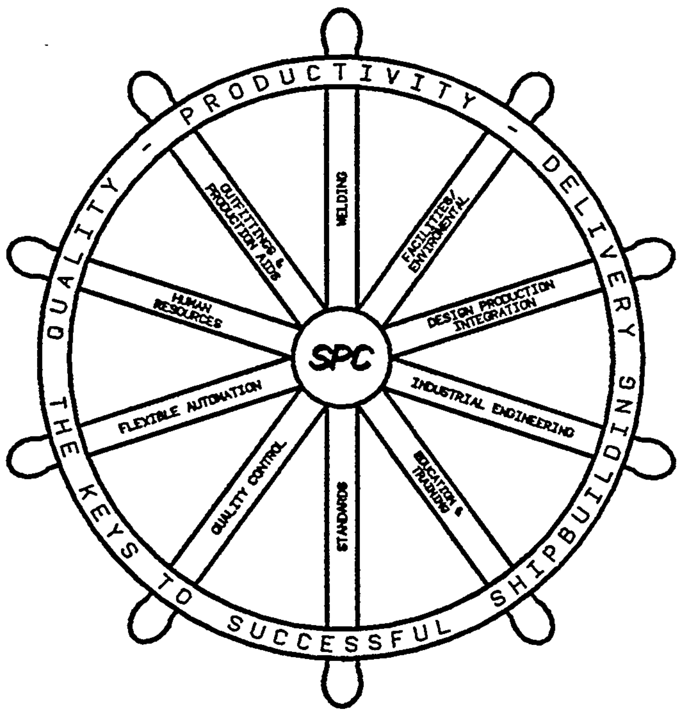

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The Design of Longitudinal Beam Layout On A Curved Shell Based on the Production-Oriented Design Concept

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ABSTRACT

A VLCC (Very Large Crude oil Carrier) has approximately one thousand curved longitudinal beams, many of which have three-dimensional complicated curvatures. Due to the shortage of highly skilled workers and the need to keep costs down, production and structural designers have worked to reduce the number of such beams.

In order to meet the requirements of production, IHI (Ishikawajima-Harima Heavy Industries Co., Ltd.) has attempted several design approaches for the longitudinal beam layout, to reduce the number of beams that have complicated curvature. Recently, through the application of a Computer Aided Design (CAD) system, which has been improved for shipbuilding based on the Calma's system, a new design method for the longitudinal beam layout has been successfully developed. A significant number of the beams with a twisted configuration were eliminated, and replaced with beams of simpler, two-dimensional shapes.

This paper shows the transition of these design approaches, and the application of the new design to building a VLCC.

INTRODUCTION

In a layout design of a longitudinally framed ship, represented by a VLCC, the longitudinal beams on the curved shell usually have a complicated configuration. These beams have three kinds of curvatures : single plane, out of plane, and axially twisted curvatures (Figure 1). These curvatures are formed in two steps at a bending shop. At the first step, the beams are cold formed on a single plane by a bending machine (Figure 2). And at the next step, they are bent out of plane and twisted at the same time by line heating (Figure 3).

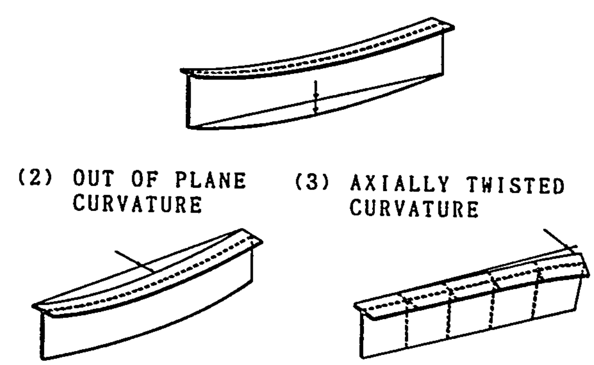


Figure 1. Three kinds of curvatures of longitudinal beams on a curved shell

Figure 2. Bending work by cold bending

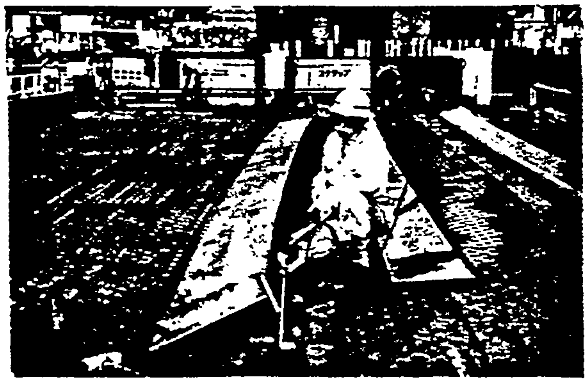


Figure 3. Twisting work by line heating

The line heating method needs skilled workers. Recently however, the number of them in the Japanese shipbuilding field have been decreasing rapidly. In order to keep productivity, quality and safety in the production shops, it is important to emphasize the production-oriented design concept. Several design approaches have been attempted for the purpose of reducing the number of longitudinal beams that have complicated curvatures.

TRANSITION OF THE LAYOUT DESIGN OF LONGITUDINAL BEAMS

The Conventional Layout Design

Essentially, the longitudinally framed layout was determined in the functional design stage. Then, in the primary layout design stage, longitudinal beams were laid to be most effective for the longitudinal strength of whole ship. That is, the beams were laid across frame lines almost normally in the body plan drawing, and were fitted normally on the shell plate (Figure 4). In this design approach, longitudinal beams on the curved shell had complicated configuration. Too many man-hours had been spent on the fabrication of these beams.

The Modified Layout Design

Thereafter, in order to facilitate block positioning at the erection stage, block seams were laid horizontally. The longitudinal beams were also laid horizontally in the body plan drawing, so as not to cross with a seam line (Figure 5). At the same time, the fitting angle of longitudinal beams was made uniform to reduce twisting work by line heating. But in this design, out of plane bending work still remained, and this bending work was usually performed with pulling tools in the fitting process at the assembly stage of a block. Also, longitudinal beams, which required twisting work, were concentrated to a few blocks; this helped to reduce the number of twisted beams.

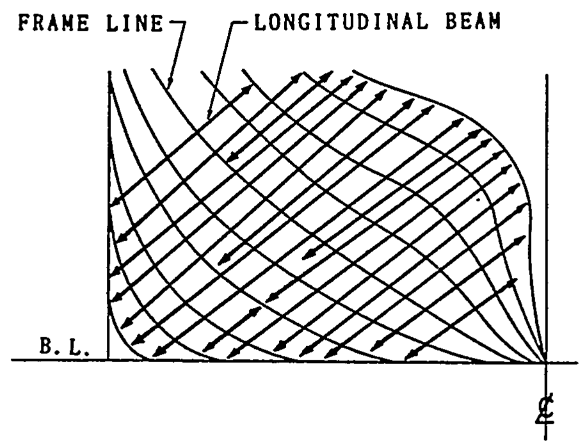


Figure 4. The conventional layout design

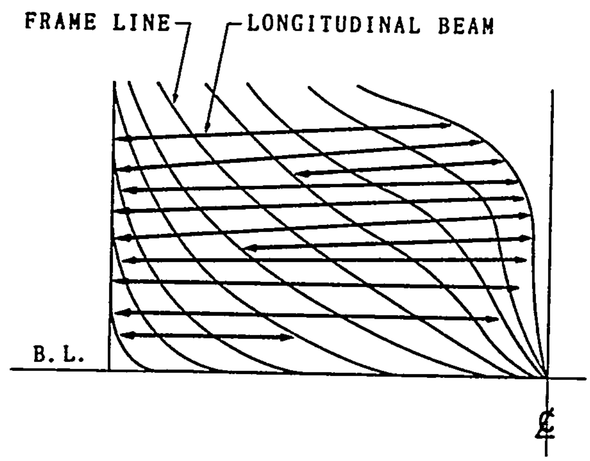


Figure 5. The modified layout design

The Advanced Layout Design

The best design for production was for the longitudinal beams to be laid on a single plane because these beams have neither twisted nor out of plane curvatures (Figure 6). In such a design, longitudinal beams should be treated as planes in three-dimensional space. This is difficult to show using conventional design methods, based on body plan drawings with two dimensions. However, such a layout of longitudinal beams can be designed easily with the proper application of a good CAD system.

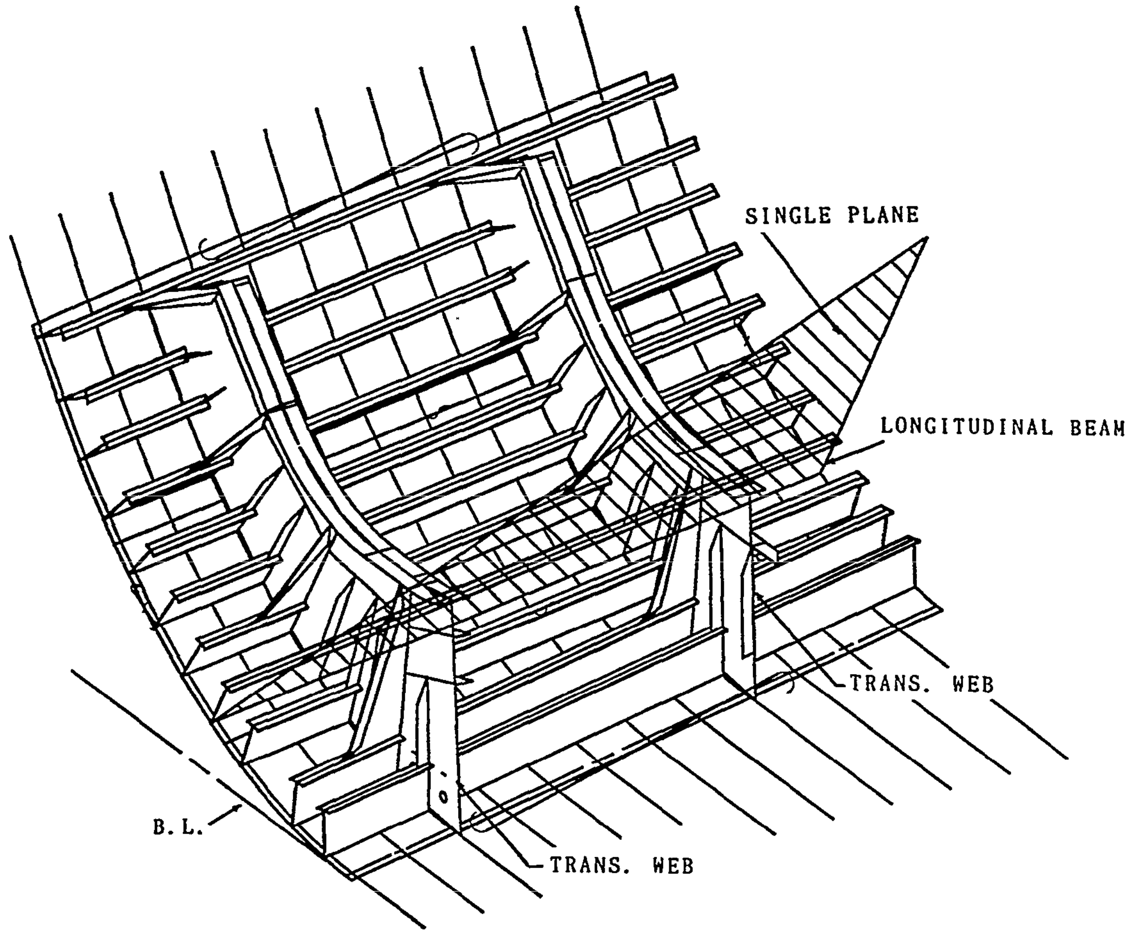


Figure 6. Example of longitudinal beams laid on single plane

DEVELOPMENT OF THE ADVANCED DESIGN METHOD OF LONGITUDINAL BEAM LAYOUT

The method of longitudinal beam layout design was improved along with the improvement of the computer system. At first, the batch system for the conventional layout design method had been developed and applied by the shipyard. At that time, the fitting lines were designed as straight lines in the body plan drawing. The operator input the coordinates of both end points of the lines, and the fitting angle of beams at both the end points. Then the operator verified the space between any two longitudinal beams, and the variation of fitting angles of beams to shell plates in the output drawing.

Thereafter, in order to improve the efficiency of the ship production design, the three-dimensional CAD system was developed. This CAD system has been applied to the layout design of longitudinal beams in the shipyard since 1986. The modifications of the space and angle of beams have been interactively carried out in the body plane view on a CAD workstation.

Using this CAD system for the advanced layout design, the fitting lines of longitudinal beams, which have only single plane curvatures, are easily given as the intersection lines of shell plate surfaces and planes on which the beams are laid. The given fitting lines are bent, not straight, in the body plan view (Figure 7).

But the application of the advanced design method of longitudinal beam layout created new problems at block butts (Figure 8):

1. The joints of longitudinal beams were slightly knuckled.
2. The corners of web and face plate of longitudinal beams were slightly deformed out of square at the joint.

Therefore, the CAD system was improved to solve the new problems interactively on screen. In order to obtain such a function, it was very important to create the three-dimensional digital mock-up in the CAD system. In the improved CAD system, the shapes of longitudinal beams were created as surface models along their shell plate fitting lines along with their attributes (scantlings and fitting angles) (Figure 9). Then, using surface models of the longitudinal beams, the modifications of knuckled angles and deformed corners of web and face plates at joints were carried out interactively.

In addition to improving the CAD system, the batch system for parts generation has been improved. This corresponds to correction of the joint deformation of the beams at block butts.

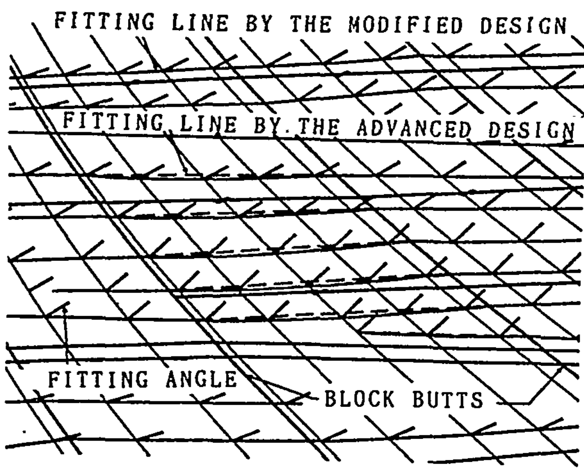


Figure 7. The comparison of the advanced design with the modified design

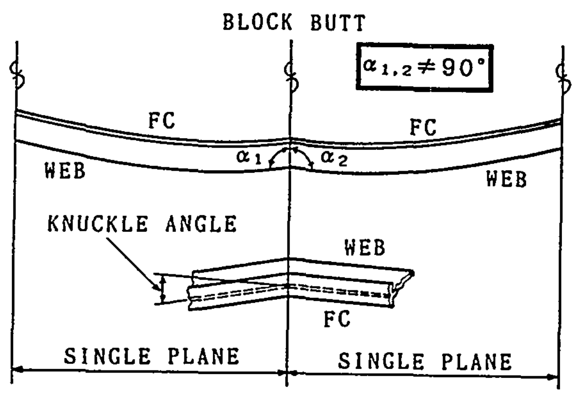


Figure 8. The new problems at block butt

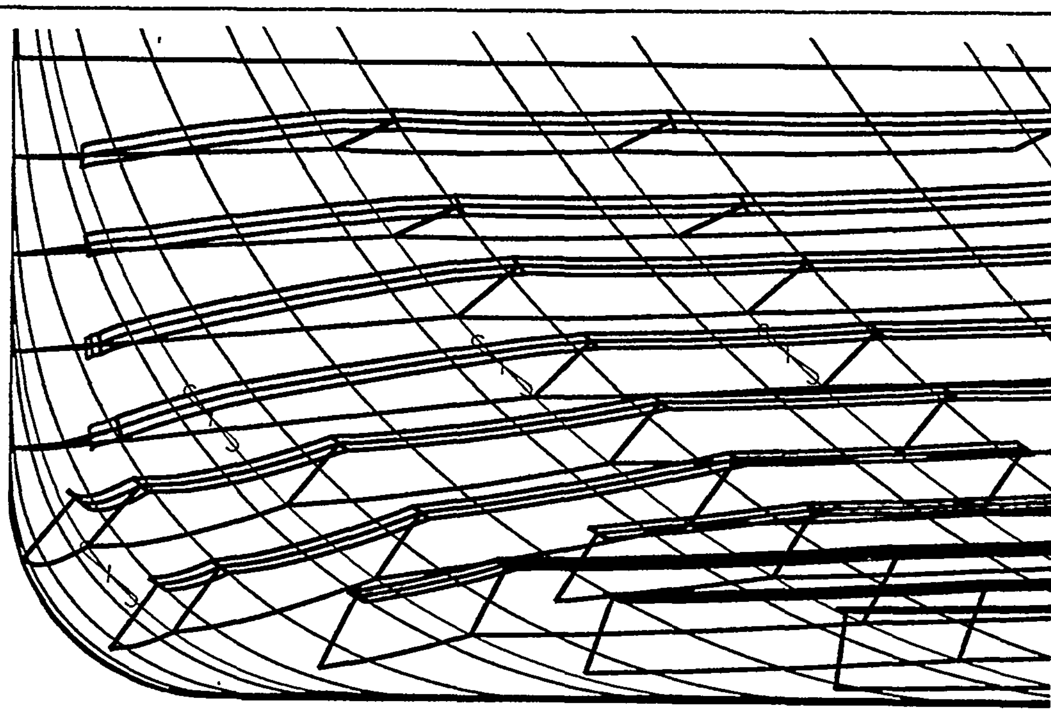


Figure 9. Surface models of longitudinal beams

CONSIDERATION FROM A STRENGTH POINT OF VIEW

To use the advanced layout design of longitudinal beams, several strength verifying calculations were carried out to justify the design change.

The space between any two longitudinal beams should be kept as close to the planned value as possible. If the space is too large, the local strength of the panel, comprised of the shell plate and longitudinal beams, will not be enough. If the space is too small, it will be difficult to control hull weight and workability at production.

The fitting angle of the longitudinal beam to the shell plate should be kept as close to 90 degrees as possible, so as not to reduce their local bending strength (i. e. their sections modulus with the shell plate). The range of possible angles is limited from 70 to 110 degrees for the beams with T shape section in the design standard. At 70 and 110 degrees, about 10% of their strength is lost, compared to the strength at 90 degrees (Figure 10).

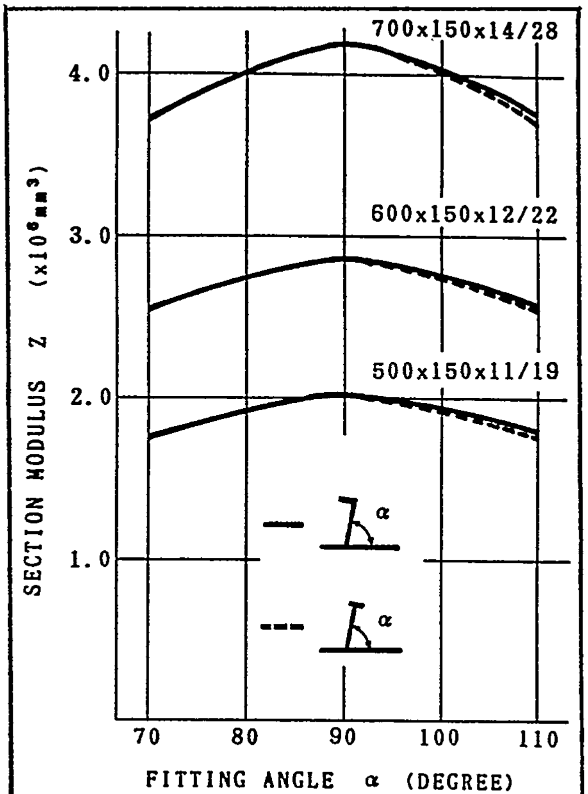
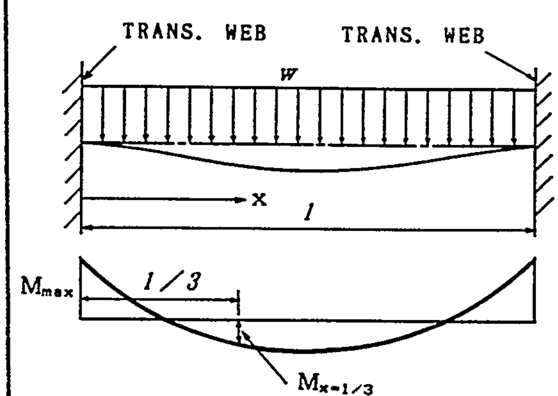


Figure 10. Section modulus of L and T shape section with plate 610 x 15 (mm)

The longitudinal beam knuckle joint at block butts is subject to local lateral deformation between transverse web frames from the stress component of a ship's longitudinal bending moment. The efficiency of longitudinal beams, which are knuckled 10 degrees at the joint, is reduced to about 70% of the efficiency at the full strength condition. But the advanced layout design is applied to side beams only on curved shell blocks, where the working stress by the ship's longitudinal bending moment is rather small. So it is considered that the influence of such reduction of strength is negligible.

Evaluating the local strength of the beams, the local bending moment is considered small at the knuckle joint as the block butt is located at about 1/3 distance of the transverse web frame spacing (Figure 11). The effect of the local bending moment is negligible.



$$M_{x=l/3} = -\frac{w\,l^2}{36} = -\frac{1}{3}M_{max}$$

Figure 11. The local bending moment diagram working on a longitudinal beam

APPLICATION TO VLCC BUILDING

In 1991 the advanced layout design of longitudinal beams was applied to the building of a VLCC in the shipyard for the first time. The following design policy was used.

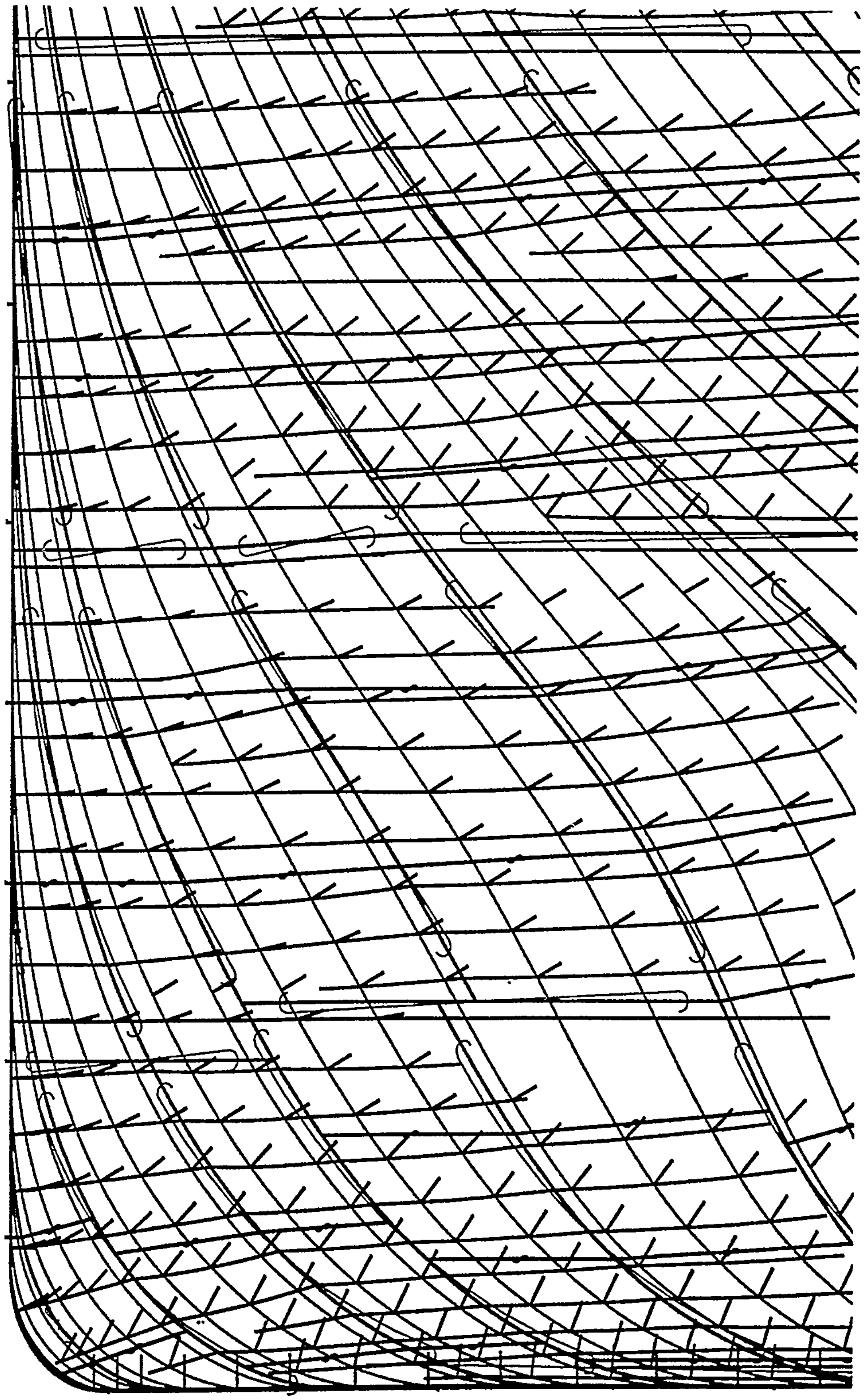


Figure 12. A part of the structural lines drawing of the VLCC applied the advanced layout design

1. Longitudinal beams were laid horizontally as often as possible in order to lessen the knuckle angle of beams at the block joint, because an increased knuckle angle enlarges the bending moment. The knuckle angle had to be less than 8 degrees.

2. The fitting angle of a longitudinal beam to the shell plate had to be larger than 70 degrees and smaller than 110 degrees.

3. Longitudinal beams with curvature in only a single plane were used as often as possible. Where a twisted curvature could not be avoided, the beams were shaped through line heating.

The latest VLCC has 950 curved longitudinal beams in the whole ship. The number of single plane curvature beams by the modified layout design was about 490. By applying the advanced layout design to the remaining curved beams, about 220 beams of complicated curvature were eliminated and replaced with beams of single plane curvature. As a result of this improvement, only 244 beams of twisted curvature remained (Figure 12).

EXPECTED EFFECTS OF THE ADVANCED LAYOUT DESIGN

In addition to the expected man-hour saving in the bending work of longitudinal beams at the bending shop, there are other effects of the advanced layout design.

Accuracy in fabrication of the longitudinal beams is improved because increased quality of single plane curvature beams contributes to fabrication of beams by a bending machine without heating.

At the assembly stage, the installation of longitudinal beams, which have neither out of plane nor twisted curvatures, saves fitting work of beams to a shell plate, and improves dimensional accuracy of the assembled curved block (Figure 13).

Then, at the erection stage, accurately fabricated joints of the block butts make the connection work easier, and man-hour is saved (Figure 14).

CONCLUSION

In today's labor market, where numbers of skilled workers in shipbuilding are decreasing, mechanization of production processes contributes to improved productivity. In this respect it is important to attempt approaches based on the production-oriented design concept. A simplified hull structure facilitates production work, and encourages mechanization of production equipment in a shipyard.

Such approaches, based on the production-oriented design concept, require the efforts of shipyard management in cooperation with production engineering, design and computer system departments.

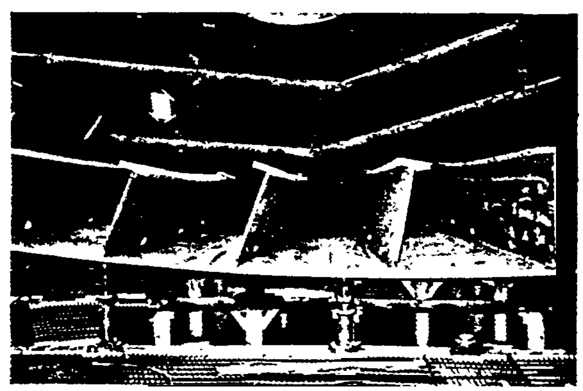


Figure 13. The block with applied advanced layout design

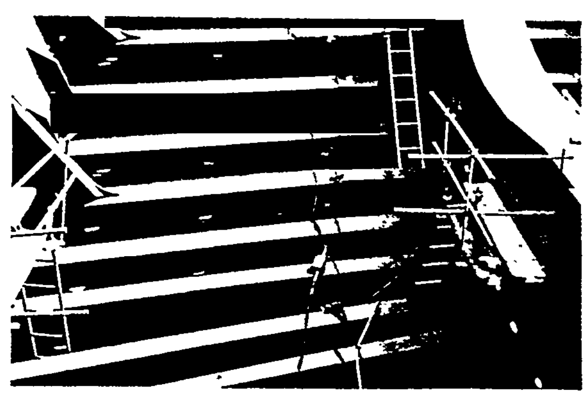


Figure 14. The block butt with applied advanced layout design

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